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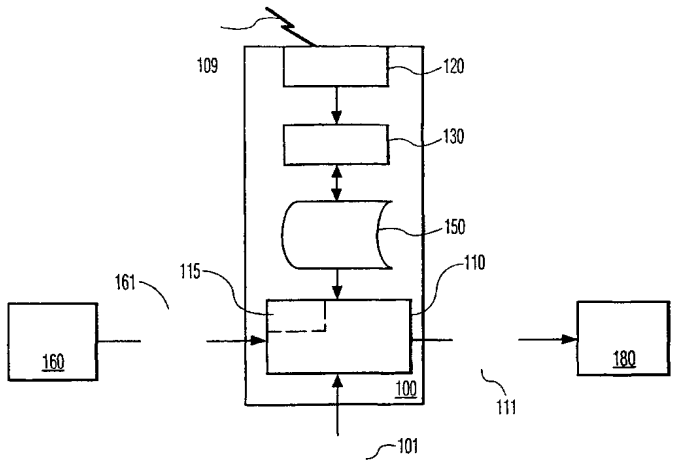
(54) Title: UPDATING A REVOCATION LIST TO FOIL AN ADVERSARY




(57) Abstract: The lists used to verify whether an access identifier has been revoked are processed and maintained in a random fashion to reduce the likelihood of a revoked access identifier being accepted for access after a passage of time. When the access control system updates its local revocation list, a non-deterministic method is used to determine the resultant content of the local revocation list. In accordance with another aspect of this invention, the communication of the revoked identifiers is also based on a non-deterministic selection of revoked identifiers. In this manner, the mere passage of time will not necessary result in a prior revoked identifier becoming revived. The replicated device will become "unreliable", in that the user can never be assured that the replicated device will operate "properly". In accordance with another aspect of this invention, the enforcement of the revocation is also randomized. For example, the access control system may initially provide the content material to a device having a revoked identifier, then, at some random time later, terminate the transmission. In this manner, a user of a replicated device can never be assured that the content material, such as a movie, can be viewed in its entirety.

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Updating a revocation list to foil an adversary

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of consumer electronics, and in particular to methods for controlling access to copyright material.

2. Description of Related Art

Digital recordings have the unique property that copies of the recorded material have the same quality as the original. As such, the need for an effective copy protection scheme is particularly crucial for the protection of copyright material that is digitally recorded. A number of protection schemes have been developed or proposed that record the content material in an encrypted form. Other protection schemes have been developed or proposed that record an encrypted key or ticket that controls the playback, or rendering, of the content material.

In a number of copy-protection schemes, keys are distributed among compliant devices, and the content material is encrypted such that it can only be decrypted by a unique key within a particular compliant device. For example, an access control system for copy protected material may initially effect a key exchange with the particular compliant device, using for example a Diffie-Hellman key exchange technique, and then encrypt a key for decrypting the content material using the exchanged key. In this manner, only the intended recipient can decrypt the content material. Generally, the access control system does not participate in the key exchange until after the particular compliant device identifies itself, and, in most cases, authenticates this identification, typically via an encrypted signature that can be verified. Other protection schemes that rely upon an identification of the receiving device are common in the art.

An adversarial party to a security system that relies on a unique identifier of a receiver, even a unique identifier that is bound via a certificate to a public key, can foil the system by imitating a valid device. That is, techniques are common in the art for replicating a device, such that, in operation, it is virtually indistinguishable from the original. A common unauthorized business practice is the sale of "black-market" or "pirated" imitations of devices that are used to gain access to protected material.

To foil an adversary, manufacturers publish revocation lists, itemizing each identifier that has been determined to be no longer valid. In principle, the access control system receives an identifier from the intended receiving device, compares this identifier to the list of all invalidated identifications, then grants or denies access accordingly. Each issuing authority periodically publishes a list of the recently revoked identifiers, and this list is communicated to each access control system, using a variety of techniques. If the access control system is a set-top box that only provides broadcast content material to a compliant recorder or display device, for example, the revocation list can be transmitted to the set-top box from the provider of the broadcast services. If the access control system is a consumer DVD player that only plays back a DVD to a compliant display device, the latest revocation list can be embedded within commercial DVD recordings. When the user of the DVD player plays a recently purchased or rented DVD recording, the DVD player reads the embedded list. When the access control system receives a new revocation list, it updates a locally stored list of revocations accordingly. Because the local list at the access control system is of finite size, each access control system is typically configured to delete the oldest revocations when space is required for newer revocations.

Unfortunately, a number of techniques are available to an adversary to counteract this protective scheme. For example, because of the finite size of local lists, a prior revoked identifier will eventually be removed from each active local list. The likelihood that a prior revoked identifier will have been removed from most local lists can be estimated, based on the age of the prior revoked identifier, the number of identifiers revoked since this prior revocation, and the average size of most local lists. Given a sufficiently large likelihood that a prior revoked identifier will have been removed from most local lists, the adversary can again distribute the replicated products based on the prior revoked identifier, with a high likelihood of customer satisfaction. Some customers may be unable to operate the replicated device, because the characteristics of their particular access control system, or the update rate of that access control system, is such that the prior revoked identifier is not yet removed from that access control system's list, but most customers' access control systems will have removed it, and thus will accept the identifier as currently valid. Alternatively, an individual user may merely store a replicated device when it is rejected by the access control system, and periodically attempt to reuse it. Once it is accepted by the access control system again, signaling the removal of the revocation from its list, the user can continue to use the replicated device for a virtually unlimited duration. Alternatively, the adversary or user can

submit a list of possible identifiers to one or more access control systems to search for an identifier that is no longer on the list.

## BRIEF SUMMARY OF THE INVENTION

It is an object of this invention to decrease the customer satisfaction with an unauthorized replication of an authorized identifier. It is a further object of this invention to decrease the benefits derived from an unauthorized replication of an authorized identifier. It is a further object of this invention to foil attempts to determine the likelihood that a particular revoked identifier will be accepted by an access control system.

These objects and others are achieved by randomizing the lists used to verify whether a received identifier has been revoked. When the access control system updates its local revocation list, a non-deterministic method is used to determine the resultant content of the local revocation list. In accordance with another aspect of this invention, the communication of the revoked identifiers is also based on a non-deterministic selection of revoked identifiers. In this manner, the mere passage of time will not necessary result in a prior revoked identifier becoming revived. The replicated device will become "unreliable", in that the user can never be assured that the replicated device will operate "properly". In accordance with another aspect of this invention, the enforcement of the revocation is also randomized. For example, the access control system may initially provide the content material to a device having a revoked identifier, then, at some random time later, terminate the transmission. In this manner, a user of a replicated device can never be assured that the content material, such as a movie, can be viewed in its entirety.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in further detail, and by way of example, with reference to the accompanying drawings wherein:

FIG. 1 illustrates an example block diagram of an access control system in accordance with this invention.

FIG. 2 illustrates an example system for providing revoked identifiers to an access control system in accordance with this invention.

FIG. 3 illustrates an example flow diagram for maintaining a local revocation list in accordance with this invention.

FIG. 4 illustrates an example flow diagram for controlling access to content material in accordance with this invention.

Throughout the drawings, same reference numerals indicate similar or corresponding features or functions.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates an example block diagram of an access control system 100 in accordance with this invention. The access control system 100 receives controlled content material 161, and, if provided an authorized access identifier 101, provides accessed content material 111 corresponding to the controlled content material 161. For ease of understanding, this invention is presented using a consumer entertainment paradigm, such as the access control techniques that are used to control access to pay-per-view transmissions, or to control the number of copies that can be made of copy-protected material. Other access control applications based on the principles presented herein will be evident to one of ordinary skill in the art. Generally, the controlled content material 161 is encrypted material, and an access device 110 within the control system 100 decrypts the encrypted material to create the accessed content material 111 for rendering to a user, for example, for display on a display device 180. The controlled content material 161 is illustrated as being provided by a playback device 160, which could be, for example, a CD, DVD, or video disc player, a magnetic tape or hard-drive system, and so on. Alternatively, the controlled content material 161 may also be provided by a broadcast, satellite, or cable service provider. As is common in the art, the controlled content material 161 may be communicated among a variety of devices, for example, to and from a recording device after being received from a service provider, and so on.

The access device 110 provides the accessed content material 111 if and only if a valid access identifier 101 is provided. Generally, the access identifier 101 is a unique identifier that is associated with a key and is digitally signed by a special key that is known only to a "trusted authority", typically an authorized vendor or manufacturer, or the provider of the service. The access identifier 101 may be contained within a "smartcard" that identifies the user, a pre-paid card purchased by the user, a set-top box that identifies an account number for charging fees, and so on. Alternatively, the access identifier 101 may be a unique identifier of a manufactured item, such as a tape recorder, that is manufactured to enforce agreed upon copy-limit standards, as discussed, for example, in copending U.S. Patent Application "Copy Protection by Ticket Encryption", serial number 09/333,628, filed 6/15/99 for Michael Epstein, Attorney docket PHA 23,457, which is incorporated by reference herein.

The aforementioned trusted authorities publish lists that comprise access identifiers that have been discovered to have been inappropriately used, and therefore revoked. For example, unauthorized copies of recorded material may contain the access identifier that was used to originally access the material, lost or stolen "smartcards" may be revoked, and so on. Consistent with prior art devices, revoked identifiers 109 may be broadcast to access control systems 100 in a variety of forms, typically via the medium used to convey the content material. The access control system 100 includes a receiver 120 for receiving the broadcast revoked identifiers 109, and a memory for containing a local revocation list 150. Depending upon the broadcast means, the receiver 120 is typically a device that extracts the revoked identifiers 109 from the medium used to convey the controlled content material 161. For example, each published DVD or CD may contain a list of recently revoked identifiers 109. The receiver 120 may also be a dedicated device that receives the broadcast revoked identifiers 109 from a cable provider via a control channel, and so on.

The local revocation list 150 is of finite size, and eventually will be filled with the received revoked identifiers 109. In accordance with one aspect of this invention, the replacer 130 is configured to randomly replace a previous entry in the list 150 with each received revoked identifier 109. The term random is used herein in the most general sense, and includes pseudo-random and any of a variety of unordered or non-deterministic selection techniques common in the art. The random selection need not be purely random, and may include a weighted-random process that may be skewed to preferably, but not exclusively, choose older identifiers for replacement. By using a random replacement technique, even if not purely random, the likelihood of a particular revoked identifier 109 being present in the list 150 is substantially less determinable than prior methods, such as First-In-First-Out, Newest-In-Oldest-out, and other conventional ordered list management techniques. Thus, an adversary cannot rely on the mere passage of time to foil the limited security provided by a finite sized local revocation list 150.

FIG. 2 illustrates an example system 200 for broadcasting revoked identifiers 109 to an access control system in accordance with this invention. The access control system may be a conventional access control system or an access control system 100 that is configured in accordance with the first aspect of this invention, discussed above. The published revoked identifiers 201 are received from one or more trusted authorities via a receiver 220, and stored in a master revocation list 250 that is substantially larger than the local revocation list 150 at an access control system 100. For example, the system 200 may

be located at a cable service headquarters, or a disc manufacturing plant, and the master revocation list 250 may be resident in a database of virtually unlimited size. In accordance with another aspect of this invention, the selector 230 randomly selects published revoked identifiers 201 from the master revocation list 250 for encoding as broadcast revoked identifiers 109 that are communicated to the remote access control system 100 via the transport media 241. The encoder 240 encodes the published revoked identifiers that are selected for broadcasting into a form suitable for the particular transport media 241. For example, the broadcast revoked identifier 109 may be a signal that is multiplexed onto a carrier wave, encoded on a track of a CD or DVD, included in the header of a VCR tape, and so on.

By randomly selecting the broadcast revoked identifiers 109 from the master revocation list 250 of all published revoked identifiers 201, the likelihood of a particular revoked identifier in the master revocation list 250 being communicated to an access control device 100 is substantially less determinable than prior methods of communicating the most recently revoked identifiers. This aspect of the invention also allows the benefits gained by random selection to be realized by some conventional access control devices, albeit to a lesser degree. That is, for example, a conventional access control device that uses a First-In-First-Out (FIFO) list management technique will be presented a random selection of revoked identifiers of various ages, and an adversary cannot rely on the mere passage of time to foil the limited security provided by a finite sized FIFO list. In like manner, the selector 230 may update the revocation date of the randomly selected identifier, so that a control access device that utilizes a conventional "oldest-out" list management technique will also be provided the benefits of this invention.

Thus, as presented herein, by utilizing a somewhat random selection technique, for either selecting the revoked identifiers that are communicated to the access device, or selecting the revoked identifiers in the local list to be replaced, or both, the likelihood of an access identifier being accepted by an access device 100 is less predictable than the prior art, ordered, techniques. Thus, the customers who purchase unauthorized devices having revoked access identifiers will experience unpredictable results. This unpredictability can be expected to decrease the popularity of such unauthorized devices, and thereby potentially reduce the market for such devices.

FIG. 3 illustrates an example flow diagram for maintaining a local revocation list, such as may be used by an access control system 100, in accordance with this invention. The initialization block 310 represents the activity before the local list of revoked identifiers

becomes full. At 320, a new revoked identifier is received, and at 330, an index into the local list of revoked identifiers is selected for placing this new revoked identifier. In accordance with the first aspect of this invention, this selection is random. At 340, the new revoked identifier is placed in the local list of revoked identifiers, at a location identified by the randomly selected index, and control returns to block 320, awaiting the next new revoked identifier.

FIG. 4 illustrates an example flow diagram for controlling access to content material, such as may be used by an access control system 100, in accordance with this invention. At 410, an access request and the access identifier are received. Not illustrated, the block 410 checks the validity of the access identifier, for example, by decrypting the access identifier using a key that is associated with the trusted authority that provided the access identifier. In response to the access request, access is initially granted for a valid access identifier, at 420, and then the access identifier is checked to see if it has been revoked, via the loop 430-450. If the access identifier matches an entry in the local list of revoked identifiers, at 440, access is terminated, at 480. In accordance with another aspect of this invention, if a match is found in the local list, the matching entry in the list is marked as non-replaceable, at 460. In this manner, the same unauthorized access identifier will not be replaced by subsequent revoked identifiers, and thereby become usable in the future. In accordance with another aspect of this invention, the access device 110 of FIG. 1 includes a timer 115, and the access is terminated after a delay, at 470. By delaying the termination of the access, a customer who acquires a device having a revoked identifier will be further annoyed by being allowed to view a portion of the content material, such as a movie, then being prevented from viewing, for example, the climax and conclusion of the movie. The time delay may be based on the duration of the content material, or it may be a fixed or random delay period. As noted above, by increasing the annoyance factor associated with devices with unauthorized access identifiers, the market for such devices can be expected to decrease.

The foregoing merely illustrates the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements which, although not explicitly described or shown herein, embody the principles of the invention and are thus within its spirit and scope. For example, copending U.S. Patent Application "Key Exchange Via a Portable Remote Control Device", serial number _____, filed _____ for Michael Epstein, Attorney docket PHA _____(Disclosure 700621), presents methods and applications for exchanging cryptography keys between authorized devices, and is

incorporated by reference herein. The principles of this invention can be applied to verify that the devices that are exchanging keys are authorized devices. The particular structures and functions are presented in the figures for illustration purposes. Other configurations are also feasible. For example, the access control system 100 of FIG. 1 may be embedded within the playback 160, display 180, or other device. In like manner, access need not be granted, in block 420 of FIG. 4, to the controlled content material until after it is verified, via the loop 430-450 that the access identifier has not been revoked. These and other system configuration and optimization features will be evident to one of ordinary skill in the art in view of this disclosure, and are included within the scope of the following claims.

CLAIMS:

1. A system comprising:

a local revocation list (150) that contains a plurality of revoked identifiers,

an access device (110) that controls access to content material (161, 111) based on a comparison of an access identifier (101) to the plurality of revoked identifiers, and

a receiver (120) that receives at least one new revoked identifier (109), and

a replacer (130) that randomly replaces at least one revoked identifier of the plurality of revoked identifiers with the at least one new revoked identifier (109).

2. The system of claim 1, wherein

the access device (110) inhibits access after a time duration from an initial access to the content material (111).

3. The system of claim 1, wherein

the time duration is based on at least one of: a duration associated with the content material (111, 161), a random duration, and a predetermined duration.

4. The system of claim 1, wherein

the access identifier (101) includes a cryptographic certification.

5. The system of claim 1, wherein

the replacer (130) excludes a previously revoked identifier in the local revocation list (150) for random replacement based on the comparison of the access identifier (101) with the previously revoked identifier.

6. A system comprising:

a receiver (220) that receives a first plurality of newly revoked identifiers (201) (201) from one or more trusted authorities,

a selector (230) that selects a second plurality of newly revoked identifiers (109) from the first plurality of newly revoked identifiers (201) and a plurality of previously revoked identifiers, and

a means for communicating the second plurality of newly revoked identifiers (109) to an access device (110).

7. The system of claim 6, wherein

the selector (230) selects the second plurality of newly revoked identifiers (109) based on a random process.

8. The system of claim 6, wherein

the means for communicating the second plurality includes:

an encoder (240) that embeds the second plurality within a medium (241) that contains content material (161).

9. A method of facilitating revocable access control comprising:

receiving (220) a first plurality of newly revoked identifiers (201) from one or more trusted authorities,

selecting (230) a second plurality of newly revoked identifiers (109) from the first plurality of newly revoked identifiers (201) and a plurality of previously revoked identifiers, and

communicating the second plurality of newly revoked identifiers (109) to an access device (110).

10. The method of claim 9, wherein

the selecting of the second plurality of newly revoked identifiers (109) includes a random process.

11. The method of claim 9, wherein

the step of communicating the second plurality includes:

encoding (240) the second plurality within a medium (241) that contains content material (161).

12. A method for controlling access to content material (111, 161), comprising:

maintaining a list of revoked identifiers (150),

receiving (320) a new revoked identifier (109),

selecting (330) a random revoked identifier from the list of revoked identifiers (150),

replacing (340) the random revoked identifier in the list of revoked identifiers (150) with the new revoked identifier (109),

receiving (410) an access identifier (101),

inhibiting (480) access to the content material (161) based on a comparison (440) of the access identifier (101) to the list of revoked identifiers (150).

13. The method of claim 12, wherein the step of inhibiting access includes

granting (420) access during an initial time duration, and

inhibiting (480) access after (470) the initial time duration.

14. The method of claim 13, further including

determining the initial time duration based on at least one of: a random process, a duration associated with the content material (111, 161), and a predetermined time duration.

15. The method of claim 12, further including

marking (460) a previously revoked identifier of the list of revoked identifiers (150) to exclude it from selection as the random revoked identifier, based on the comparison of the access identifier (101) to the list of revoked identifiers (150).

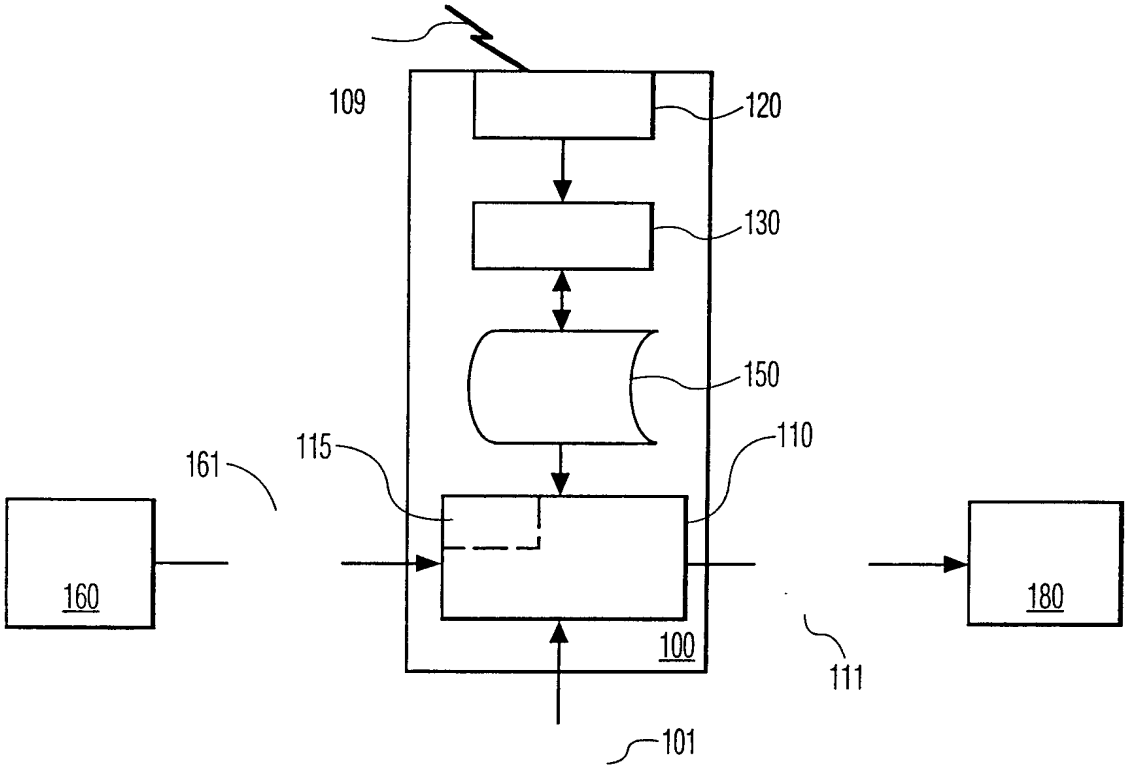
109
120
130
150
115
110
161
160
180
100
111
101

FIG. 1

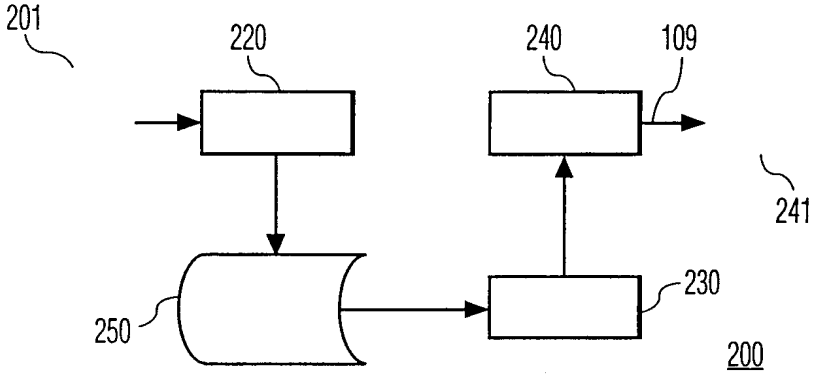
201
220
240
109
241
250
230
200

FIG. 2

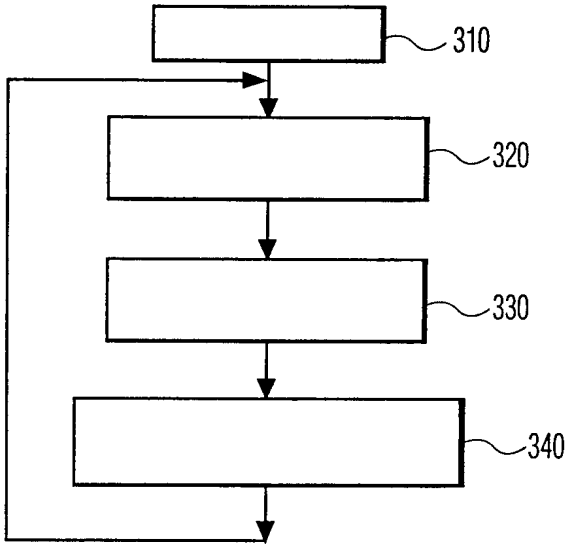


FIG. 3

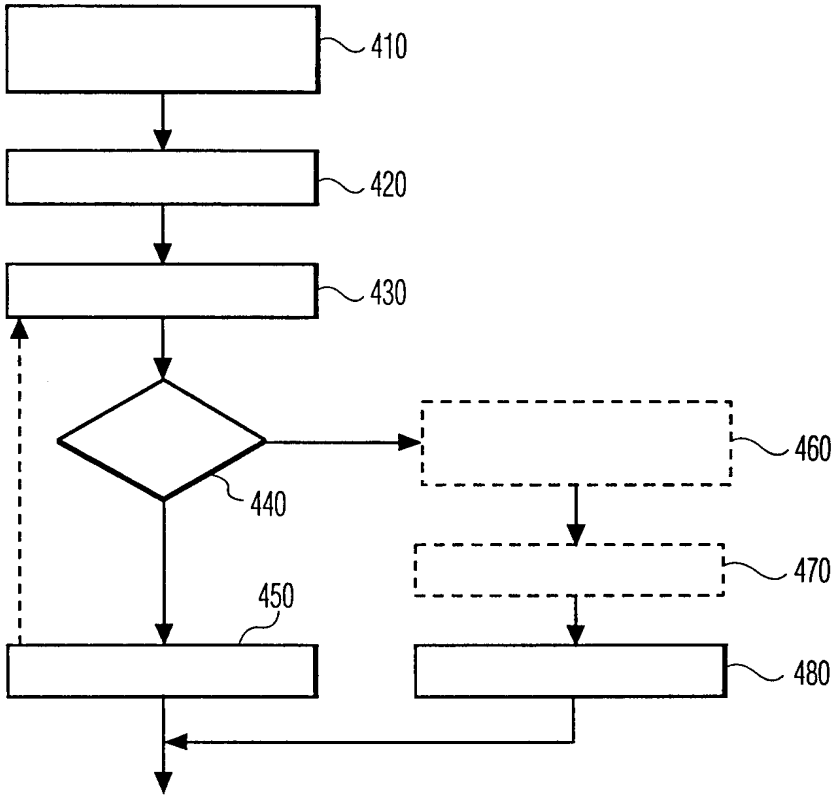


FIG. 4

# INTERNATIONAL SEARCH REPORT

Interna al Application No
PCT/EP 00/07275

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L9/32 G06F1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L G06F G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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| A | US 5 699 431 A (HILLIER STEPHEN W ET AL)<br>16 December 1997 (1997-12-16)<br>abstract<br>column 2, line 34 - line 62<br>column 4, line 25 - line 67 | 1,2,6,9,<br>12 |
| A | US 5 261 002 A (KAUFMAN CHARLES W ET AL)<br>9 November 1993 (1993-11-09)<br>the whole document | 12,13 |

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 10 November 2000 | 21/11/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Schiwy-Rausch, G |

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Form PCT/ISA/210 (second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Interna' al Application No
PCT/EP 00/07275

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication,where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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...ormation on patent family members

Interna... al Application No
PCT/EP 00/07275

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